NESTING SUCCESS OF WESTERN BLUEBIRDS (*SIALIA MEXICANA*) USING NEST BOXES IN VINEYARD AND OAK-SAVANNAH HABITATS OF CALIFORNIA

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ABSTRACT.—Loss of oak woodlands to vineyard development in California is a growing concern to conservationists. Analyzing breeding performance of birds that nest in and around vineyards versus those that nest in nearby native habitat can provide information on the suitability of vineyard environments to birds. We placed predator-protected nest boxes in vineyard and oak-savannah habitats and monitored nest-box occupancy, nesting success, and life history characteristics of Western Bluebirds (*Sialia mexicana*) that used the boxes. Western Bluebirds were common occupants in both habitats, occupying >50% of available nest boxes. Analysis using program MARK revealed that nest survival was not associated with habitat type; however, clutch size was greater and nests were initiated earlier in vineyard than in oak-savannah habitat. Our results suggest that when naturally occurring nest sites are limiting, vineyards could be converted to good breeding habitat for Western Bluebirds with the addition of nest boxes. Nest boxes, however, should not be viewed as a remedy for the chronic problem of habitat loss and degradation. *Received 27 June 2005, accepted 5 May 2006.*

The loss of oak woodland habitat to vineyard expansion is a growing concern in California (Zack 2002). More than 100 bird species breed in California's oak woodlands (Verner 1980), making the loss and degradation of this habitat particularly problematic. In San Luis Obispo County, California, land used for viticulture increased from 4,008 to 10,851 ha between 1996 and 2000 (Mummert et al. 2002). Conservationists generally view vineyards as sub-optimal habitat for birds due to the potential impacts of pesticides and herbicides, habitat fragmentation, attraction of nonnative bird species and predators, loss of wildlife shelter and forage, and changes to the native plant community. The ecological consequences of this large-scale habitat conversion, however, are not well understood.

The addition of nest boxes has been found to augment nesting success and breeding densities of secondary cavity-nesting bird (SCNB) species in altered habitats (Brawn and Balda 1988, Twedt and Henne-Kerr 2001, LeClerc et al. 2005). In golf course habitats, Le Clerc et al. (2005) found that nest boxes provide high-quality nesting habitat for Eastern Bluebirds (*Sialia sialis*). Little is known, however, about the nesting success of SCNB species that breed in vineyards compared to those that breed in native oak woodland, and it is unknown whether vineyards that feature nest boxes provide adequate breeding habitat for the closely related Western Bluebird (*Sialia mexicana*). The main objective of our study was to compare breeding performance and life history characteristics of Western Bluebirds using nest boxes in a minimum-impact vineyard with bluebirds using nest boxes in native oak-woodland habitat.

METHODS

Study site and study species.—We studied Western Bluebirds on the Santa Margarita Ranch, approximately 25 km north of San Luis Obispo in central coastal California, during the breeding seasons of 2003 and 2004. This privately owned, 5,700-ha property surrounding the town of Santa Margarita (35° 23.39′ N, 120° 36.55′ W) features a working cattle operation and 1,000 acres comprising the Cuesta Ridge Vineyard. The dominant tree species on the study area are valley oak (*Quercus lobata*), blue oak (*Q. douglasii*), coast live oak (*Q. agrifolia*), California foothill pine (*Pinus sabiniana*), and willow (*Salix* spp.). The understory is predominantly open and consists primarily of annual grasses and forbs, including ryegrass (*Lolium* spp.), wild

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oat (*Avena* spp.), brome (*Bromus* spp.), milkweed (*Asclepias* spp.), and exotic weeds such as star-thistle (*Centaurea* spp.) and other thistles (*Cirsium* spp.). Unlike typical California vineyards, which comprise large, contiguous tracts of trellised vines, the Cuesta Ridge Vineyard is a minimum-impact vineyard characterized by smaller planted areas that follow contours of the surrounding hills and the retention of relict oak trees (*Quercus* spp.) in, and adjacent to, the vineyard.

The Western Bluebird is the most common SCNB species on the study area. It is migratory, returning in late winter and initiating nest building in early March. This insectivorous species is monogamous and is known to rear one to two broods over the spring and summer, with both parents caring for the young (Guinan et al. 2000). Other SCNB species on the study area included Tree Swallow (*Tachycineta bicolor*), Violet-green Swallow (*Tachycineta thalassina*), Ash-throated Flycatcher (*Myiarchus cinerascens*), and House Wren (*Troglodytes aedon*).

Nest boxes.—During January and February 2003, we placed 120 nest boxes in each of two habitat types on the Santa Margarita ranch: oak-savannah and vineyard. The oak-savannah habitat was open oak woodland (≤10% canopy coverage) characterized by grassland and scattered oak trees. We placed vineyard nest boxes ≤12 m outside of the vineyard edge because placing nest boxes in the middle of a vineyard matrix would have interfered with daily vineyard management. To reduce anthropogenic disturbance and minimize home-range overlap between bluebird pairs nesting in vineyard versus oak-savannah habitats, we placed oak-savannah nest boxes ≥300 m from any vineyard edge.

Boxes were constructed of rough-cut cedar fence board using a plan developed by the North American Bluebird Society and featured in Berger (2000). The boxes were modified such that they opened from the top instead of from the side. In each habitat type, we randomly selected 30 points that were then used as starting points for lines of four nest boxes. Each line featured two nest boxes with large-diameter entrance holes (3.9 cm) and two boxes with small-diameter entrance holes (3.2 cm). Entrance hole sizes were chosen to promote nesting by native SCNBs and to prevent nesting by nonnative cavity nesters, such as European Starlings (*Sturnus vulgaris*) and House Sparrows (*Passer domesticus*). Using metal hose clamps, we mounted two boxes of different entrance hole sizes back-to-back on a single 2.4-m-high T-post; the other two boxes were mounted singly on two separate T-posts. To minimize the chances of nest predation, we used bailing wire to fasten a 61-cm-long, 5.1-cm-diameter PVC pipe to each T-post directly under the nest box. Foam sealant was injected into the core of the PVC pipe to prevent snakes and small mammals from climbing between the post and the PVC. The mounted boxes were then placed in lines of three T-posts spaced 100 m apart to decrease nest-site competition between Western Bluebird pairs (Perren 1994). The four boxes were placed such that two entrance holes faced east and two faced west. Box placement (paired or single) and direction (east or west) were assigned randomly.

Nest box monitoring.—In 2003, we monitored nest boxes every 7–14 days throughout the nesting season, which was sufficient for accurately determining rates of nest-box occupancy but not nest stages and fates. From March to May 2004, we inspected each nest box at least every 7–10 days. Once we found a nest box with signs of nesting activity, we determined the initiation date and monitored the nest box at 3–4 day intervals to determine its status; when stage transitions (e.g., onset of incubation, hatching, and fledging) were expected, we monitored nests every 1–2 days (Ralph et al. 1993, Martin et al. 1997). To reduce the possibility of forced fledging (Keyser et al. 2004), we did not open nest boxes after Western Bluebird nestlings were 14 days old. For nest boxes with bluebird nestlings older than 14 days, we evaluated the nest status by observing parental behavior and listening for nestlings in the box. We monitored each Western Bluebird nest until all young had fledged or the nest had failed. We considered a nest successful if it was empty within 2 days of the calculated fledging date and there was no sign of predation and/or if we observed fledglings in the area (Martin et al. 1997). We checked each nest 1–2 days after the calculated fledging date to confirm the presence of a family group in the area.

Habitat measurements.—In 2004, we measured nine habitat variables at each nest box after the young fledged or the nest failed. Many of the measurements were based on those used in the BBIRD protocol (Martin et al. 1997). Variables included slope, aspect, and orientation of the nest-box entrance, distance to the nearest vines, and the distance to and the height and DBH of the nearest tree. Within 10 m of the nest box, we used a spherical densiometer to measure percent canopy cover and we visually estimated the percent cover of shrubby, downed woody material, forbs, and grasses. We defined "distance to nearest perch" as the distance to the nearest tree in oak-savannah habitat and distance to nearest vines in vineyard habitat. This variable provided an index of perch-site availability in the two habitats.

We measured the interior temperature of four nest boxes in 2004 (two in vineyard and two in oak-savannah habitat) by fastening a HOBO H8 (Onset Computer Corp., Bourne, Massachusetts) temperature data logger to the T-post and extending a thermocouple inside the nest box. For each box, temperature readings were recorded every 15 min during the entire nestling stage (37–39 days).

Statistical analyses.—We used a χ^2 goodness-of-fit test (Zar 1996) to compare observed versus expected nest-box occupancy in oak-savannah and vineyard habitat. We used the nest survival model in program MARK (White and Burnham 1999) to model effects of biologically relevant factors, such as habitat (vineyard and oak-savannah) on daily survival rate (Dinsmore et al. 2002). Model A included nest survivorship as a function of the grouping variable (habitat), and model B assumed constant survivorship over time. We used Akaike's Information Criterion corrected for small sample size (AIC_c) to compare the set of *a priori* candidate models (Burnham and Anderson 1998). The best model was selected by evaluating the degree of support for each model using the AIC_c values and normalized Akaike weights (w_i; Burnham and Anderson 1998). The Akaike weight evaluates the strength of evidence for each model; the higher the weight, the stronger the model (Burnham and Anderson 1998). We examined the relationship between mean clutch size and initiation date using a linear regression and tested the significance of the regression with an F-test (Zar 1996).

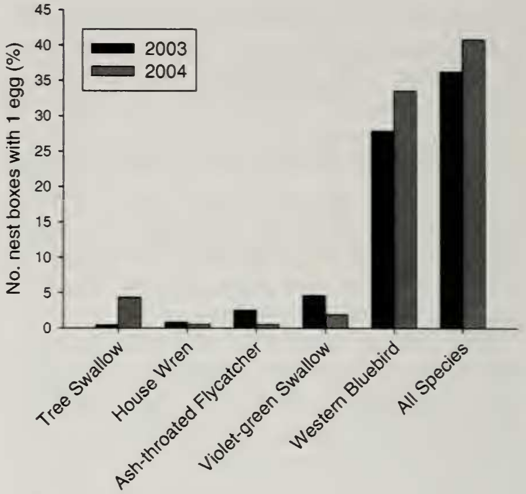

FIG. 1. Nest-box occupancy (%) of 120 nest boxes used by secondary cavity-nesting bird species on the Santa Margarita Ranch, San Luis Obispo County, California, in 2003 and 2004.

We used a Shapiro-Wilk statistic (SPSS Institute, Inc. 2003) to test all variables for normality. We then used Mann-Whitney U-tests (Zar 1996) to test for habitat-based differences in clutch initiation date, clutch size, number of eggs hatched, number of young fledged, slope, percent canopy cover, and distance to the nearest perch.

RESULTS

Nest box occupancy.—Western Bluebirds were the most common nest box occupants across habitats and years (Fig. 1). Western Bluebirds occupied 27.9% and 33.6% of all nest boxes in 2003 (n = 240) and 2004 (n = 208), respectively (Fig. 1). Nest boxes with the smaller diameter entrance hole were unavailable to bluebirds; therefore, considering only available boxes, bluebirds occupied 55.8% of the boxes in 2003 and 67.3% in 2004. In 2004, Western Bluebirds used nest boxes in oak-savannah and vineyard habitats in proportion to their availability (χ^2 = 0.91, df =1, P = 0.34).

Nesting success.—In 2004, we monitored 70 Western Bluebird nests (n = 39 in vineyard and n = 31 in oak-savannah). In program MARK, model A (habitat) estimated daily nest survival for the nesting period (i.e., egg-

TABLE 1. Variables (mean ± SE) describing nesting success of Western Bluebirds at the Santa Margarita Ranch, San Luis Obispo County, California, 2004.

Variable	Habitat		*P*-value
	Vineyard	Oak-savannah	
Number of nests	39	31	•
Clutch size	5.28 ± 0.08	4.97 ± 0.12	0.040
Number of nestlings per nest	4.90 ± 0.14	4.63 ± 0.21	0.465
Number of fledglings per nest	4.69 ± 0.14	4.63 ± 0.24	0.799
Initiation date (days since 1 January)	88.61 ± 1.56	92.58 ± 1.48	0.053

laying to fledging) at 0.995, and model B (constant survivorship) estimated it at 0.998. Furthermore, AICc values for model A (100.162) and model B (100.729) were similar, indicating that habitat type did not affect the survival of Western Bluebird nests on the Santa Margarita Ranch. Of the 70 nests, 10 (14%) failed, including only two (3%) probable predation events: one nest appeared to be depredated during the nestling stage by a snake, and ants swarmed the other during the incubation stage. The other eight (11%) failed nests contained either dead chicks or cold eggs, and we assumed that they were abandoned. At least one chick fledged from each of the remaining 60 (86%) nests.

Life-history characteristics.—Clutch size for many avian species has been found to decline over the course of the breeding season (Perrins and McCleery 1989, Hochachka 1990, Winkler and Allen 1996). In 2004, there was not a significant relationship between mean clutch size and initiation date for Western bluebird nests across treatments (r^2 = 0.11, df = 5, $F_{1,4}$ = 0.51, P = 0.51). Clutch sizes were larger in the vineyard than in oak-savannah (5.28 ± 0.08 versus 4.97 ± 0.12; Mann-Whitney U = 461.00, P = 0.040) and nests were initiated significantly earlier in vineyard habitat than in oak-savannah (Mann-Whitney U = 400.50, P = 0.036; Table 1). However, we found no statistically significant difference in number of nestlings (Mann-Whitney U = 473.50, P = 0.47) and number of fledglings (Mann-Whitney U = 416.00, P = 0.80) for nests in vineyard versus oak-savannah in 2004 (Table 1).

Habitat measurements.—Mean percent canopy cover around the nest boxes did not differ by habitat (5.73 ± 3.44 in oak-savannah versus 6.28 ± 3.14 in vineyard; Mann-Whitney U = 604.00, P = 0.95). We found a difference in mean distance to perch site (Mann-Whitney U = 84.5, $P < 0.001$) between nests in vineyard and oak-savannah; on average, perch sites were closer to nest boxes in the vineyard (11.44 ± 0.39) than in the oak-savannah (35.64 ± 4.21) habitat. Mean maximum temperature in nest boxes was 28.50° C ± 0.63 in oak-savannah and 28.53° C ± 0.65 in vineyard habitat. Mean minimum temperature in nest boxes was 6.22° C ± 0.27 in oak-savannah and 6.14° C ± 0.27 in vineyard habitat. Mean maximum temperature (t-test: t = 0.042, df = 74, P = 0.97) and mean minimum temperature (t = −0.232, df = 74, P = 0.82) inside the nest box over the nestling period did not differ between habitat types.

DISCUSSION

The results of this study indicate that vineyard habitat, with its limited availability of naturally occurring nest sites, could be converted to good breeding habitat for Western Bluebirds with the addition of nest boxes. In the two habitat types, Western Bluebirds were the most common nest-box occupants (>55%). In 2004, nest survival was high across habitats; at least one chick fledged from 86% of the nests. It should be noted, however, that predator guards were included on all of our nest boxes, as they are a common component of many commercially available nest-box designs, and the high nest survival and fledging rate that we observed could have been an effect of the predator guards. Thus, the high rate of nest survival that we report should be interpreted cautiously.

Clutch initiation date and clutch size differed between bluebirds nesting in vineyard versus oak-savannah habitat. Bluebirds nesting in the vineyard initiated nesting earlier and laid larger clutches than those in oak-savannah habitat. Habitat differences in food supply have been shown to affect the timing of egg laying and clutch size among passerines (Blondel et al. 1993, Siikamaki 1995), and the predictable water supply provided by daily irrigation at Cuesta Ridge Vineyard may have supported a larger insect population in the vineyard. In turn, this could have allowed female bluebirds to start laying earlier and to lay more eggs. There was no significant difference, however, between the two habitats in terms of number of nestlings or young fledged.

Nest boxes in both vineyard and oak-savannah habitats did not differ with respect to percent canopy cover or interior nest-box temperatures. However, the Cuesta Ridge vineyard was structurally different from the majority of vineyards in San Luis Obispo County: it was composed of smaller areas of vines that encompassed large valley oaks adjacent to large patches of native oak woodland. Therefore, our results may not be representative of conditions in other vineyards in the area. Additional research is needed in the more traditional vineyards, which are typically characterized by large, flat expanses of vines and a lack of large trees.

Adding nest boxes to certain habitats has been found to increase the breeding densities of several species of SCNBs (Brawn and Balda 1988, Newton 1994, Twedt and Henne-Kerr 2001). However, density can be a misleading indicator of habitat quality (Van Horne 1983). Therefore, adding nest boxes to vineyard habitats may enhance those habitats so that they serve as population sources that could stem the decline of Western Bluebirds; conversely, such vineyards could be functioning as "ecological traps" (Delibes et al. 2001, Mänd et al. 2005), population sinks that yield no net reproduction. It is important to note that our survival and productivity results come from a single breeding season and from a minimum-impact vineyard; also, nestling condition and post-fledging survival were not quantified. Additional research investigating post-fledging survival and nest-site fidelity are needed in vineyards with nest boxes to clarify their role as population sources or sinks.

Though our data indicate that vineyards with nest boxes provide suitable breeding habitat for bluebirds, nest boxes in vineyards should not be viewed as a remedy for the chronic problem of habitat degradation and loss of oak woodlands. Møller (1989) and Purcell et al. (1997) also warned against using nest boxes as a cure-all for declining populations. Whereas nest boxes may be an effective, short-term conservation tool for enhancing or maintaining populations of SCNBs—Western Bluebirds in particular—they do not mitigate the effects of chronic habitat loss for the many species that occupy oak woodland habitats in California.

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